# Marine Biological Sound West of San Clemente Island

## Diurnal Distributions and Effects on Ambient Noise Level During July 1963

P. O. Thompson

Research Report

24 May 1965

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA 92152 · A BUREAU OF SHIPS LABORATORY

NEL / REPORT 1290

# PROBLEM

Conduct surveys of biological sounds in the ocean. In particular, study effects of biological sound on observed base ambient noise levels in the San Nicolas Basin near San Clemente Island, using hourly recorded samples from two widely separated hydrophones resting on the bottom at 60 and 450 fathoms.

# RESULTS

1. Of the impressive variety and quantity of biological sound in the samples eight types were found to be most prevalent.

2. The sound types were assigned the following descriptive names: Click Chorus, Rhythmic Grunt, Motor-boating, Barking, Growl, Low-Frequency Groan, 20 c/s Long Pulses, and 20 c/s Short Pulses.

3. The first three types listed were strongly diurnal, all showing greatest prevalence at night.

4. Barking and 20 c/s Long Pulses were present during essentially all the 192 hours monitored, both at the shallow hydrophone and at the deep hydrophone.

5. An almost-continuous drone of Rhythmic Grunt appeared to be largely responsible for an increased base ambient noise level that occurred in the 80 c/s to 300 c/s region peaking just before midnight at the deep hydrophone. The cause of a high plateau observed in this frequency range at the shallow hydrophone from 2100 to 0300 hours was not identified.

6. Peaks in the base ambient noise level at 2000 and 0400 hours in the 160 c/s to 1000 c/s range at the shallow hydrophone were mainly the result of increased activity of the Click Chorus.

# RECOMMENDATION

Conduct further studies at the same locations during the same month of the year using additional equipment to obtain *directional* sound information and underwater visual information, in order to determine the sources of the sounds in the area.

# ADMINISTRATIVE INFORMATION

The work was assigned by BUSHIPS letter 688-057 of 9 Dec 1960 and was performed under SF 001 03 16, Task 8529 (NEL E11351) during the period January 1964 through December 1964. The report was approved for publication 24 May 1965.

Acknowledgment is due G. M. Wenz, for general consultation and for furnishing the tape recordings and $\frac{1}{3}$-octave-band strip-chart records for this study. The author is also indebted to G. M. Wenz, M. A. Calderon, and T. F. Scanlan for the field data and other information in NEL Report 1260 which were helpful in writing this report. The field work described in NEL Report 1260 was accomplished under SR 004 03 01, Task 8119 (NEL L20451).

# CONTENTS



# ILLUSTRATIONS



REVERSE SIDE BLANK

# INTRODUCTION

This report records the results of a survey of the biological sound present in a set of tape recordings obtained during an 8-day period in July 1963 off San Clemente Island in the San Nicolas Basin during sound propagation experimentation. The results of studies of the signal and ambient background levels have already been reported by Wenz *et al.*[1]* The propagation experiment involved a "shallow" hydrophone in 60 fathoms about 1 mile off Eel Point on the west shore of San Clemente Island and a "deep" hydrophone in 450 fathoms of water about 4 miles farther offshore to the west. Both hydrophones were mounted on tripods which rested on the bottom. The outputs of the hydrophones were recorded side-by-side on magnetic tape. These recordings yielded an average of 12 minutes of ambient noise sampling each hour continuously over the 8 days, 15-23 July. Details on instrumentation and procedure can be found in reference 1.

The data tapes were recorded at 3.75 inches/sec. The recordings were played back through a three-range speaker system, one channel at a time, using a variable band-pass filter for audio analysis when necessary. In addition to monitoring at normal and double tape speeds, listening was also performed at a playback ratio of 4 to 1 in order to raise the low-frequency sound (down to 20 c/s) to more suitable listening frequencies. The spectrographic equipment used was the Kay Electric Co. Sonagraph Model Recorder; the spectrum-time plots obtained are referred to in this report as "Sonagrams."

---

*Superscript numbers denote references in the list at the end of this report.

# THE CATEGORIES OF BIOLOGICAL SOUND

Table 1 and the first nine figures show some characteristics of the sounds found to be common in these San Nicolas Basin recordings. The meanings of the terminology used in the table will become more clear as each sound type is described. Each of the first five figures describes

TABLE 1. MAIN TYPES OF BIOLOGICAL SOUND HEARD

| Assigned name | Frequency Range (c/s) | Max. S/N (c/s) | Sound Duration (sec) | Sound Period (sec) | Pulse Duration (msec) | Pulse Period (msec) |
|---|---|---|---|---|---|---|
| 1. Click Chorus | 125-1000 | 500 | --- | 30 | 5 | 670 |
| 2. Rhythmic Grunt | 50-300 | 125 | 1 | 5 | 200 | 350 |
| 3. Motorboating | 120-1000 | 160 | 4 | 8 | 20 | 75 |
| 4. Barking ("yelp") | 160-2000 | 400 | 0.3 | 0.8 | --- | --- |
| 5. Growl | 300-1500 | 700 | 3 | 4 | 3 | 35 |
| 6. Low-Freq. Groan | 20-70 | --- | 1.5 | --- | --- | --- |
| 7. 20 c/s Long Pulse | 19.5-22 | 22 | 18 | --- | --- | --- |
| 8. 20 c/s Short Pulse | 19-40 | 20 | 0.6 | --- | 600 | --- |

one of the five most distinctive and common biological sounds in the recordings. Each figure consists of at least one Sonagram, which shows a combination of frequency, time, and gross relative amplitude; a spectrum plot from a

single sound sample, which shows relative $\frac{1}{3}$-octave level versus frequency; and an oscillographic photo, which shows voltage amplitude versus time. Included in each spectrum plot is a rough approximation of the relative ambient background level, indicated by a dashed-line curve. When the spectrum curve rises well above the dashed curve, the difference is due to the biological sound plus or minus the error of positioning of the background curve. However, a peak at 60 c/s due to equipment hum is sometimes present.

The names assigned to the various sounds represent an attempt to be as descriptive as possible, yet brief. No means was available for connecting any sound positively to any particular source; so, for example, the barking was not called "sea lion barking" even though the source of the barking in all probability was the sea lion.

Sound 1, the cyclic Click Chorus (fig. 1), has previously been described.[1,2,3,4] The individual click could just as well be called a snap or a clap or a knock and is very similar to what is often heard by Navy sonarmen and commonly referred to as the "carpenter" sound. The carpenter sound, however, does not have the cycling or surging characteristic of this chorus and usually has a wider frequency range. This sound during daylight hours may consist of single trains of pulses at a pulse repetition rate of 1.5 per second and comes in for only a few seconds during a 5-minute sampling period, for example. During nighttime hours, however, it always sounded like the result of hundreds of individuals knocking in concert typically for 20 seconds or so and then tapering off as the result of one individual after another momentarily stopping. During the next few seconds the number of individuals knocking would have decreased enough to reduce the ambient noise intensity by up to 10 dB. Sometimes the number clicking was much smaller than usual and the clicking part of the cycle was shorter. On the other hand, during the 2000 sample period, which was one hour after sunset, the apparent number of individuals clicking was at a maximum, and the density and intensity of the sound were at a constant high level without the characteristic cyclic variation.

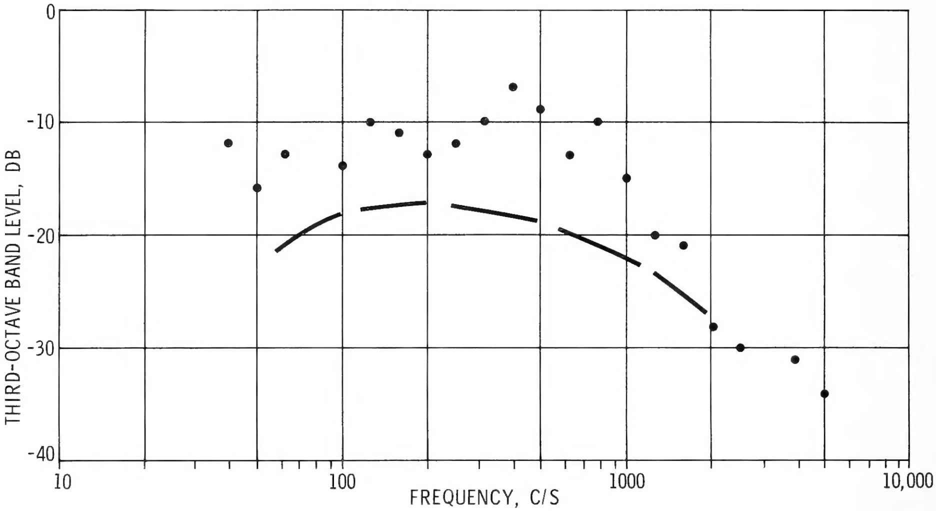
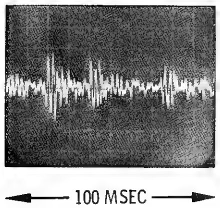



*Figure 1. Sonagram, oscillogram, and spectrum plot of Sound 1, the cyclic Click Chorus. According to the oscillogram the duration of a click is about 10 msec. In the Sonagram the traces around time 2 seconds are due to Barking activity. The speed-up of the tape playback was 4 to 1, which reduced the effective width of the Sonagraph 45 c/s analyzing filter to 11 c/s.*



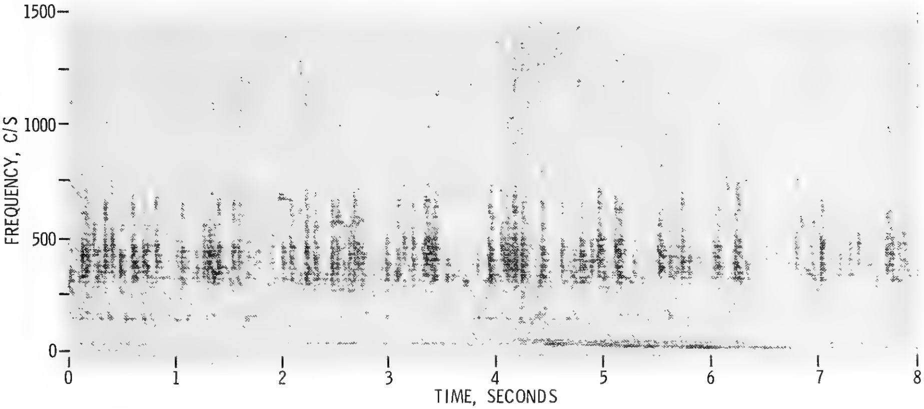




*Figure 1. (Continued)*

Sound 2, the Rhythmic Grunt (fig. 2), is similar to a frog croak and is very probably made by swim-bladder muscles, which are among the most important producers of sound in the fish world. The number of pulses in a grunt varied from one to five, and the number of pulses in a grunt from an individual source showed a tendency to repeat from one grunt to the next. Individual pulses were triangular in shape with a duration that varied between 100 and 300 msec. The grunt repeated at intervals that ranged between 4 and 6 seconds. The Rhythmic Grunt sound was present at both hydrophones, mainly during the night hours.

Sound 3, Motorboating (fig. 3) resembles the noise of a one-cylinder engine running slowly. Similar sounds emanate from ride vehicles in amusement parks. Characteristically, the start of the Motorboating pulse train was not noticed because it was masked by background noise, but the sound gradually increased in intensity over its typical 4-second duration and then abruptly terminated. The pulse repetition rate was approximately 13 pulses per second. Motorboating was mainly prevalent at night in shallow water in groups of two or more pulse trains, usually in train pairs. The interval between the terminations of the first and second members of a pair was generally 7 or 8 seconds. This sound also is probably generated in a swim-bladder muscle system.

Sound 4, Barking (fig. 4), is very similar to a dog's barking, and most people familiar with seals or sea lions would without hesitation identify it as originating in this type of animal. The Sonagram in figure 4 shows one combination of Barking (yelps and snorts, alternately one and then the other, the yelps being the patterns that are higher and more extensive in frequency). Actually, this figure represents just one vocalization combination. On other occasions the sounds could be described as chuckling, chattering, gargling, moaning, etc. For the purpose of this report all these sounds will be considered as Barking.

Sound 5, the Growl (fig. 5), is another sound that can almost certainly be attributed to the sea lion, because it

was closely interwoven with the other sounds typical of the sea lion in particular and pinnipeds in general, but was considered separately because of its possible echo-location function. The author has heard a sea lion making a very similar sound in air at the San Diego Zoo. The sound consists of a pulse train lasting several seconds and usually is preceded by a guttural vocalization as shown in figure 5 at time 0.5 second. The pulse repetition rate is about 30 per second.

Sound 6, the Low-Frequency Groan (fig. 6), is a low-frequency tonal sound, beginning at from 60 to 100 c/s and ending 1 or 2 seconds later at from 20 to 40 c/s. At least some groans, such as that shown in figure 6, consist of two components, the fundamental and a strong second harmonic which dominates because of the positive correlation between frequency and aural response below 1000 c/s in man. Sonagrams A and B show the same groan, but with different frequency and time scale combinations, as received at the shallow hydrophone. The third Sonagram shows what was received at the deep hydrophone. It is matched with the shallow hydrophone presentation shown above it, and the pair illustrates a case in which the difference in time of arrival indicates that the source was seaward from the deep hydrophone (the time difference approximated the maximum possible with the 4-mile separation of the hydrophones).

Figures 7 and 8 illustrate with Sonagrams the two kinds of 20 c/s Pulses, the Long and the Short. Such 20 c/s pulses, particularly short ones of approximately 1-second duration, have received much attention during the last 8 years.[1,5,6,7,8,9,10] Both types were prominent in the San Clemente recordings, especially the 20 c/s Long Pulses which were detected in all the recorded samples. These Long Pulses are of two types, which have already been designated Types I and II.[1] Samples of each are shown in figure 7. Examples of Type I occurred at times 1' 30" and 3' 45" and a good example of Type II occurred at time 0. The second harmonic content of the Type II Pulses is evident at 43 c/s and the second harmonic traces of the

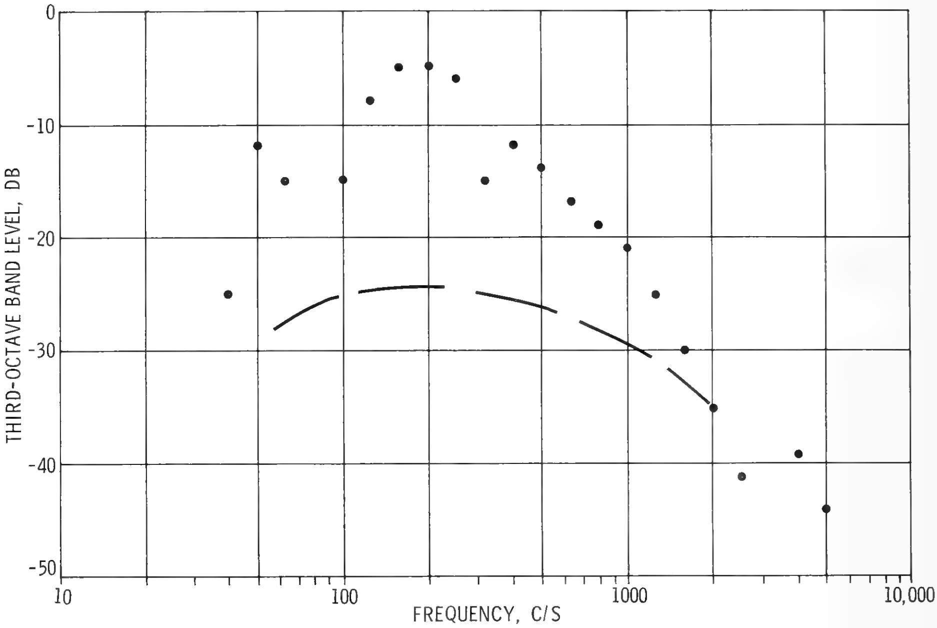
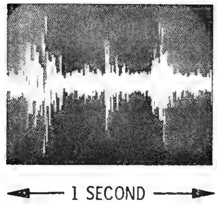
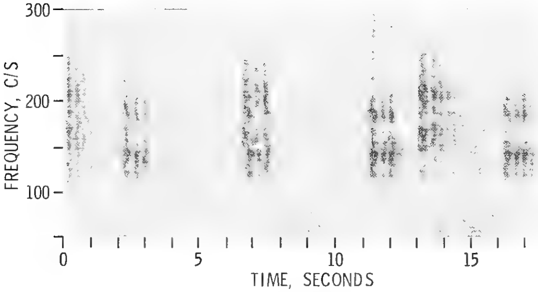



*Figure 2. Sonagrams, oscillogram, and spectrum plot of Sound 2, the Rhythmic Grunt. As shown in the 8-sec Sonagram these Grunts have little energy above 300 c/s and are composed of pulses perhaps averaging 200 msec in duration. Grunt pulses from one source can be seen from time 2 to 3 sec and again at time 7 to 8 sec. The Grunt in the 4 to 5 sec period is from a second source and is slightly higher in frequency. The wavy (horizontal) lines at 350 c/s intervals are from Barking activity and the vertical striations ending at time 3.75 sec are from a cycle of the Click Chorus. In the 17-sec Sonagram the tape playback speed was increased to 16 to 1 and the Sonagraph 45-c/s filter was effectively 3 c/s wide. More Grunts can be seen in this Sonagram and the frequency detail is spread out more. The Grunts beyond time 11 sec are the same as in the lower Sonagram. Four of the Grunt sounds seem to be from the same source.*



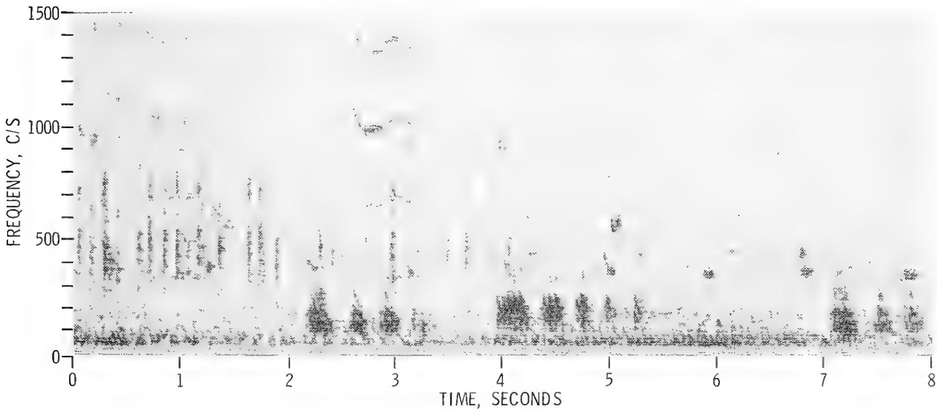




*Figure 2. (Continued)*

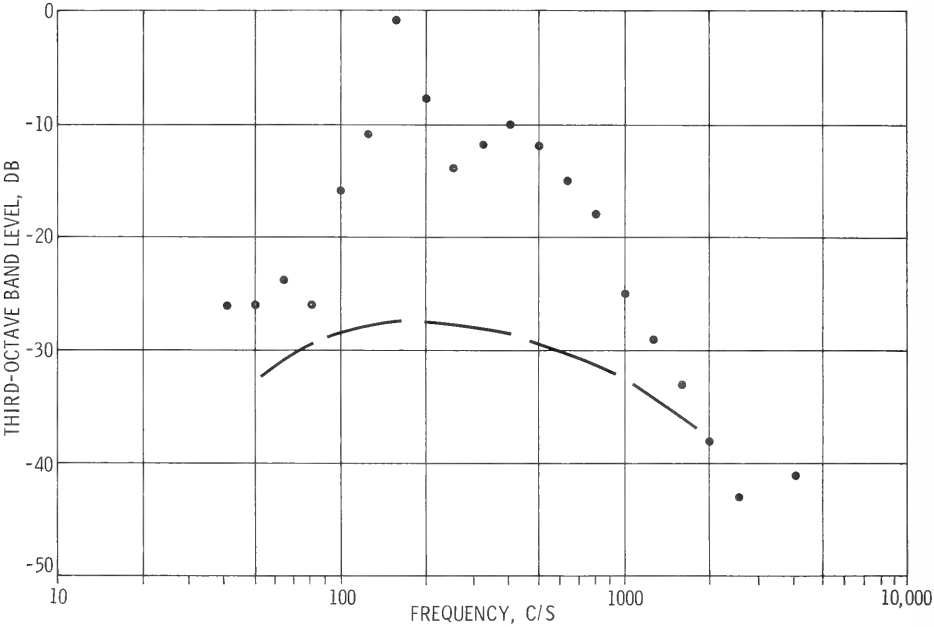



*Figure 3. Sonagrams, oscillograms, and spectrum plot of Sound 3, Motorboating. The sound is basically a pulse train with a pulse rate of 13 per sec. The 15-sec Sonagram with its effective 3 c/s filtering shows about 20 frequency components at 13 c/s intervals, the one at 150 c/s being by far the strongest. Rhythmic Grunt signals can be seen at 0.5, 4.5, 12.0, and 15.7 sec on this Sonagram. In the 4-sec Sonagram, which was made with only a 2 to 1 speed-up of the tape playback (22 c/s effective filter-width), weak Click Chorus and Barking signals can be seen in the background.*

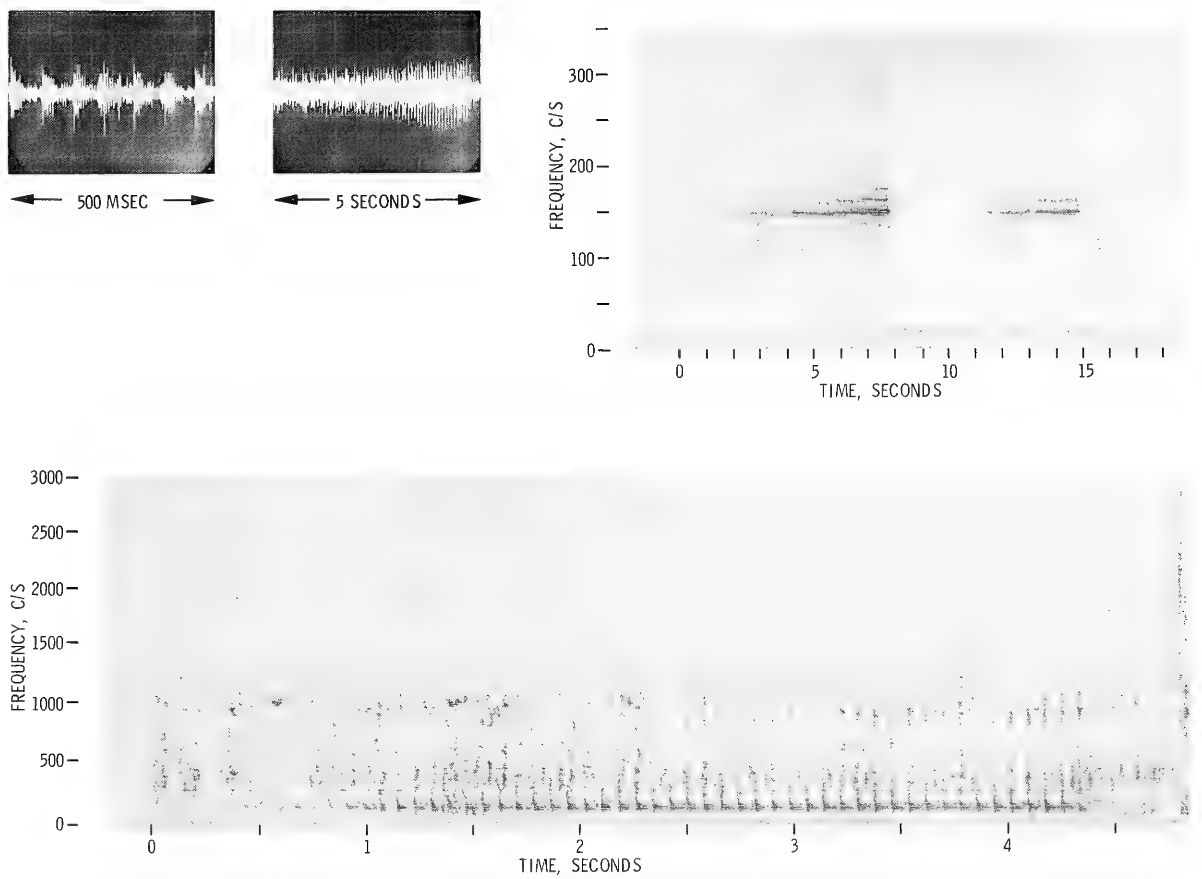



Figure 3. (Continued)

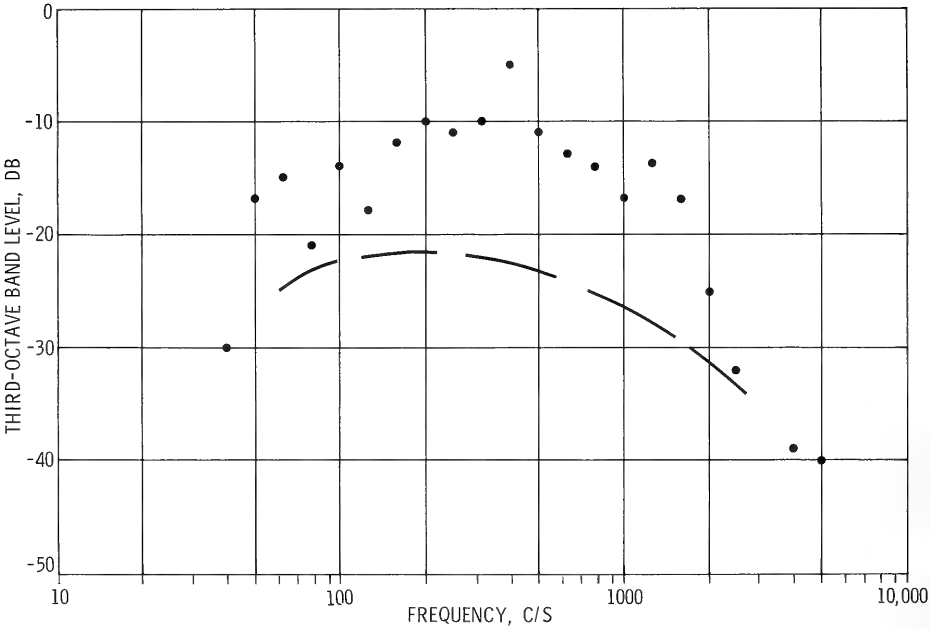
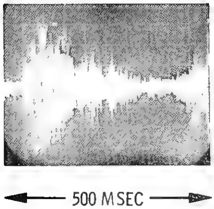



*Figure 4. Sonagram, oscillogram, and spectrum plot of Sound 4, Barking. The barking that extends to 3000 c/s can best be described as "yelps." The alternate sounds extending up to 1000 c/s can best be described as "snorts."*



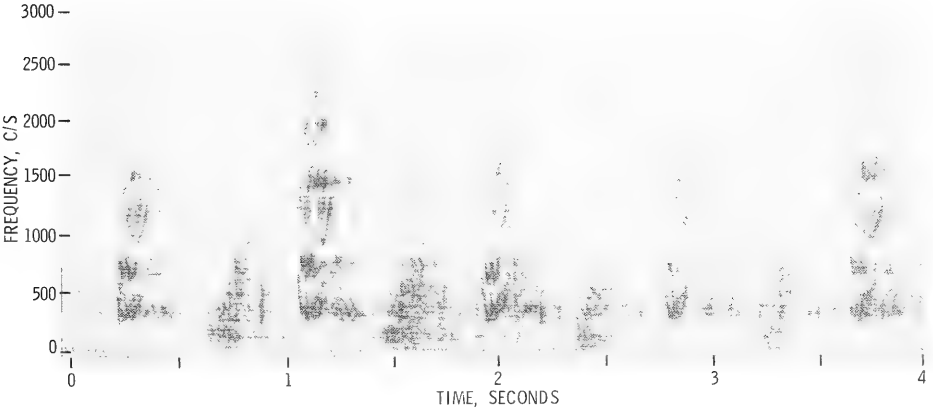




*Figure 4. (Continued)*

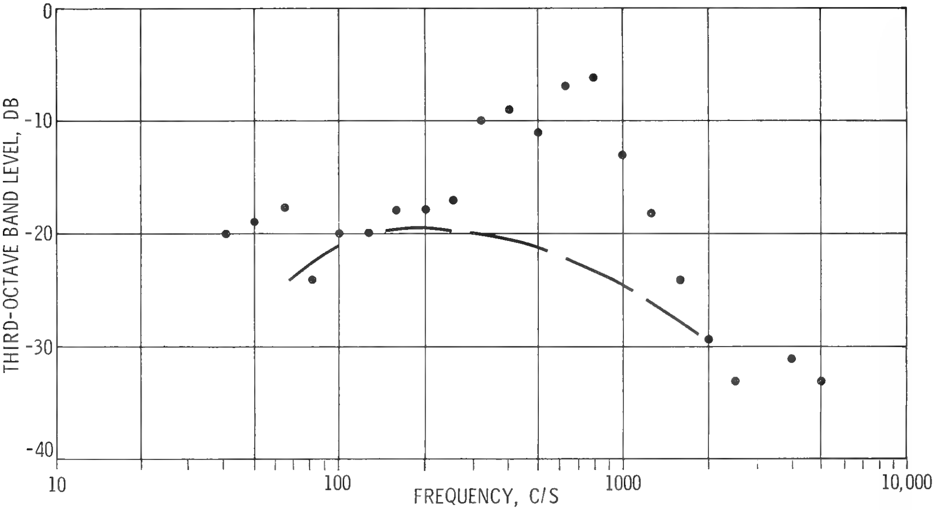
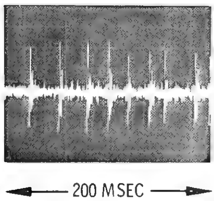
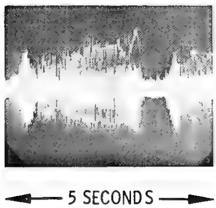



*Figure 5. Sonagram, oscillogram, and spectrum plot of Sound 5, the Growl. The pulse-train energy is distributed in two bands centered at 375 and 750 c/s. The preliminary sound between times 0.2 and 0.8 sec is like a short moan. The pulse rate within a train is decidedly variable from pulse to pulse.*



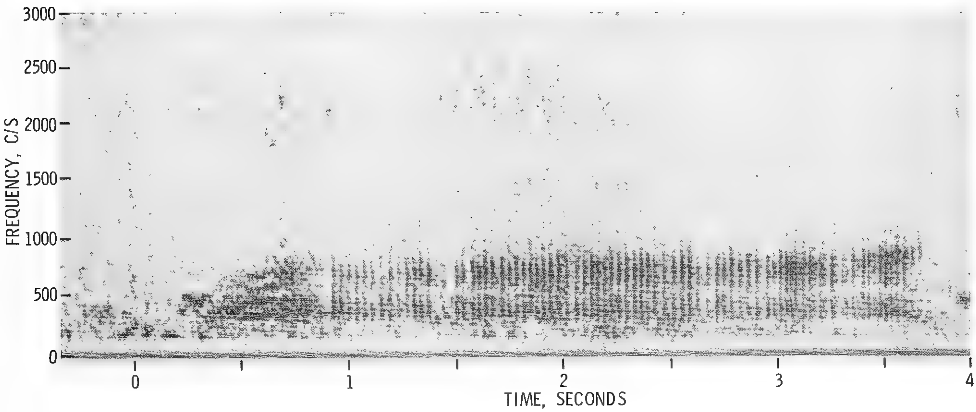




*Figure 5. (Continued)*

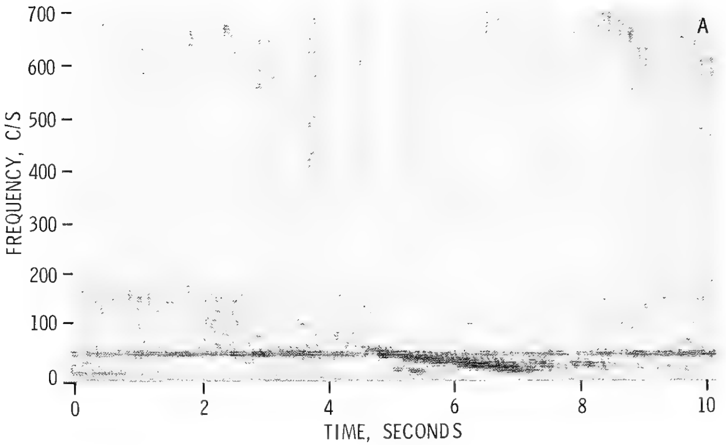



*Figure 6. Sonagrams showing the Low Frequency Groan sound. A. Groan from shallow hydrophone (between sec 4 and 7). B. Same groan with changed time and frequency scales (resulting from different tape playback speed). C. Same as B only from the deep hydrophone, arriving 4 sec earlier. The strong horizontal line is probably from equipment hum. The vertical striations in A are from the Click Chorus.*

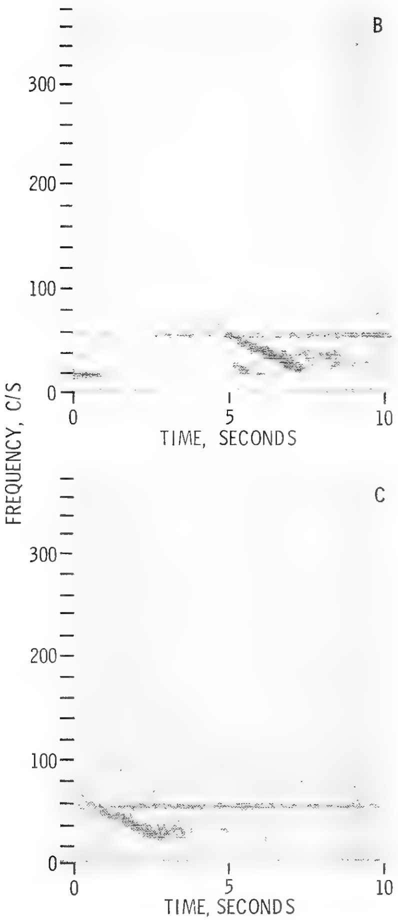



*Figure 6. (Continued)*

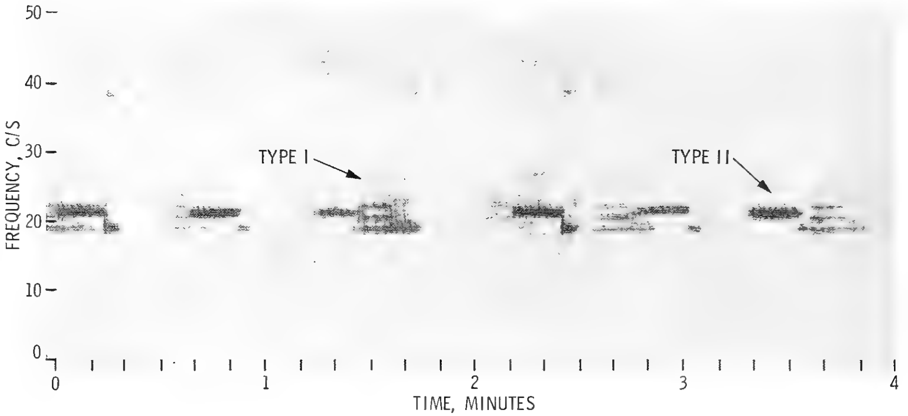



*Figure 7. Sonagram of 20 c/s Long Pulses. The Long Pulses are on the order of 20 seconds in duration and are of two types. Type I Long Pulses occur at 1'30" and 3'40". Type II Long Pulses occur at 0, 0'40", 2'10", 2'50", and 3'20".*

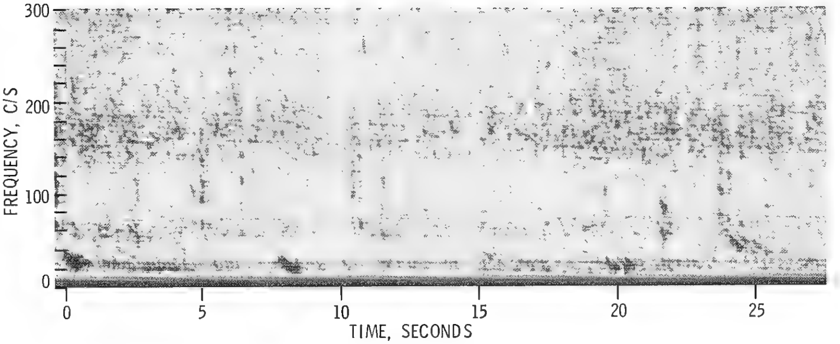



*Figure 8. Sonagram of 20 c/s Short Pulses. They occur at 0, 8, 15, and 20 sec, exhibit intrapulse frequency shift from as high as 40 c/s, and are of the order of 1 sec in duration. (The vertical striations are from the Rhythmic Grunt sound.)*

Type II tails are even more evident (38 c/s). The overlap of the pulses shown in this Sonagram is typical and suggests the probability that the pulses are from multiple sources.

Sounds in the 20 c/s region pose difficulties not only in on-the-spot study, but also in detection and monitoring. The main problem is that below 100 c/s human audition is relatively insensitive and gets rapidly worse as frequency goes down. However, an increase of speed (and frequency) of recorded samples by a factor of four results in an auditory presentation suitable for monitoring the 20 c/s Pulse activity without losing perspective relative to the other sounds.

Figure 8 shows a series of 20 c/s Short Pulses at time 0, 8, 15, and 20 seconds. The Short Pulse characteristically shows downward frequency shift and ends close to 20 c/s. Except for the average frequency and uniformly short duration, it is not greatly different from what has been called the Low-Frequency Groan. Although the pulse at time 24 seconds has the characteristic shortness of a 20 c/s Short Pulse, it is twice as high in frequency, and for the purposes of this survey is considered to be a Low-Frequency Groan.

Characteristically, 20 c/s Short Pulses occur clustered in time. Sometimes the pulse intervals within a cluster are very regular and the clusters can be considered as pulse trains. Typical intervals range from about 20 seconds to 10 seconds. Sometimes the pulse intervals are very irregular and also not readily interpreted in terms of multiple sources. Usually, a pulse cluster begins abruptly and ends abruptly. The 20 c/s Short Pulses found in this survey generally had very low signal-to-noise ratio and some were almost completely masked by the 20 c/s Long Pulses. For this reason an attempt to establish the number of sources and pulse interval would not be worthwhile.

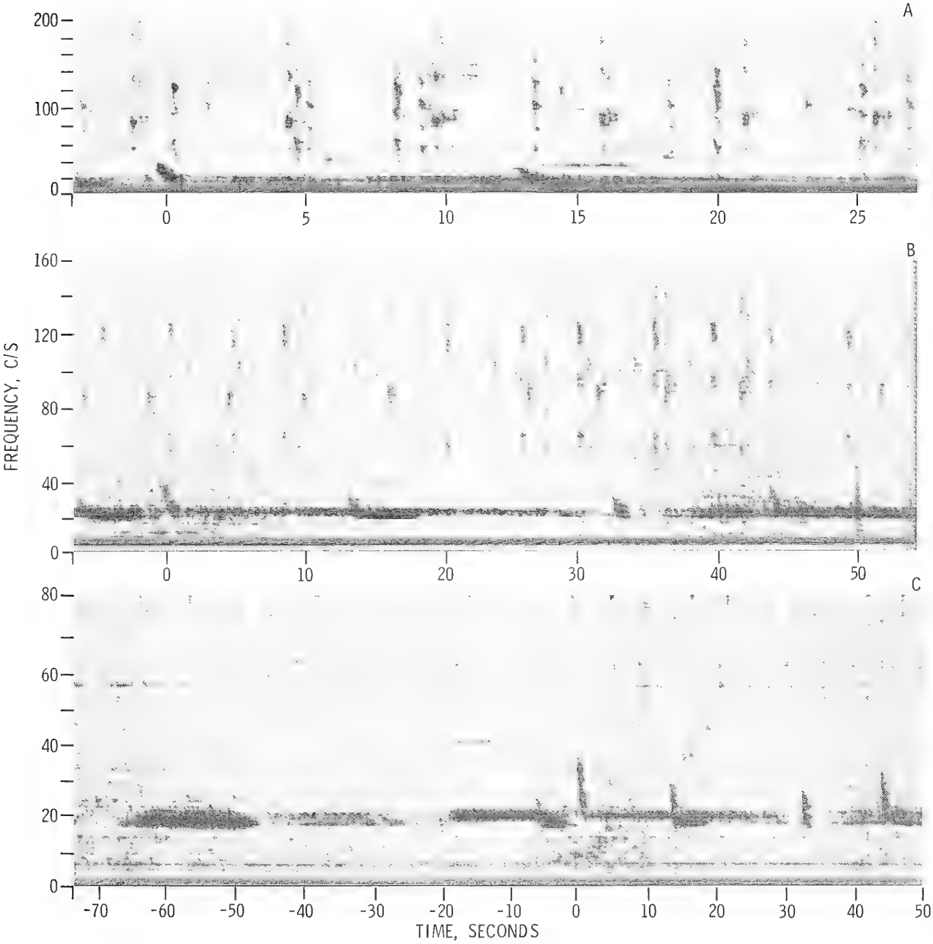
Figure 9 shows a mixture of 20 c/s Short and Long Pulses as well as other biological sound. In figure 9A Short Pulses can be seen at 0 and 13 seconds, while the

Rhythmic Grunt sound is prominent throughout. The Grunt at -1.5 seconds is really four grunts in rapid succession with frequency components at 40 c/s intervals. In contrast, the Grunter that sounds at 5, 9, 13, and 18 seconds makes a single grunt with frequency components at 25 c/s intervals. The Motorboating sound is illustrated at 2 seconds and 11 seconds as a series of harmonic-component lines. Component spacing corresponding to a pulse repetition rate of 13 per second is apparent. As mentioned above and illustrated in figure 9A, the onset of this sound is unobtrusive, and the pulse-train intensity gradually increases during its 5-second duration to a dramatic climax followed by 4 seconds of silence before a repetition of the pulse train. Pairing of Motorboating pulse trains, such as shown here, is a common occurrence.

Figures 9B and 9C show five 20 c/s Short Pulses from -7 seconds to +44 seconds. As shown in figure 9C, the first, third, and fourth seem to shift from 28 c/s down to 19 c/s and appear at intervals of 20 seconds, approximately, a characteristic interval for 20 c/s Short Pulses in this part of the Pacific. On the other hand, the second and fifth Short Pulses seem to be two of a kind, shifting from about 35 c/s down to about 22 c/s, and are separated by a long 45-second interval.

Figure 9C also shows a typical Type I 20 c/s Long Pulse beginning at time -68 seconds and lasting roughly 20 seconds, and a typical Type II 20 c/s Long Pulse beginning at -20 seconds, shifting from 22 to 19.5 c/s at -6 seconds, and terminating at -2 seconds. This latter sample also shows a strong second harmonic. The other 20 c/s Long Pulse activity is indistinct, probably because the sources involved are at greater distances.

*Figure 9. Sonagrams showing a combination of 20 c/s Short Pulses and Long Pulses, Rhythmic Grunts (vertical striations between 50 and 150 c/s) and Motorboating (closely-spaced horizontal lines in the top Sonagram between 120 and 180 c/s). The frequency detail of the Motorboating sound rather than the time detail of its individual pulses is emphasized in this case because of the great (16 to 1) speedup of the tape playback, which resulted in an effective analyzing filter bandwidth of 3 c/s and great time compression. All three Sonagrams are from the shallow hydrophone output and have the same zero time reference.*



A
B
C
FREQUENCY, C/S
TIME, SECONDS

## PATTERNS OF OCCURRENCE

The results shown in figures 10 and 11 indicate in how many days of the 8-day total the individual sounds were present during a particular hour of the day, but do not indicate the frequency of occurrence within the sample, the number of sources involved, or any measure of signal level. Because of the great fluctuation in the means from one hour to the next the curves were smoothed, using the method of running averages.[11] Three of the sounds tabulated were heard exclusively from the shallow hydrophone: the Click Chorus, Motorboating, and Growl. As suggested by figure 10, the cyclic Click Chorus was always present during night hours, while in only about half of the days was it present at all around midday. This type of graph does not do justice to the diurnal nature of this sound, since the number of sources and density of the sound are so much greater during the night hours. As can be seen in figure 10, the Rhythmic Grunt diurnal characteristic was different at the two hydrophones. The sound's frequency of occurrence increased gradually from early afternoon until early evening at the shallow hydrophone and until late evening at the deep hydrophone. It seldom was noted after 0100 at the shallow hydrophone and after 0400 at the deep hydrophone.

A sound that was always present was Barking. Barking was heard in all samples from both hydrophones. On the other hand, the least common of the sounds tabulated was the Growl sound. It was present in only 23 of the samples and all of these were from the shallow hydrophone. These data are shown in figure 11. The Growl sound seemed to be one of a large variety of pinniped-type sounds and was of interest because of its possible functional importance, for instance, to a pinniped pulse train "sonar." The fact that this sound was almost never heard during the night hours may be due to the higher ambient background levels at night, together with the relatively low signal level of the Growl. Weak pulse trains of similar pulse repetition rate and frequency range, but without the characteristic

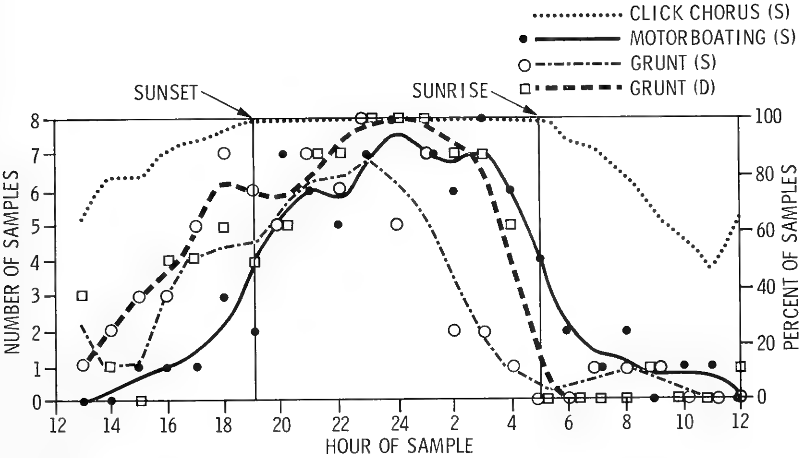



*Figure 10. Diurnal distribution curves for three sound categories with marked diurnal patterning, based on the number of hourly samples in which a particular sound was heard, regardless of how many times within a sample it was repeated. Two sound categories were peculiar to the shallow water hydrophone (S), while the Rhythmic Grunt sound was common at both the shallow hydrophone and the deep hydrophone (D). The curves were arithmetically smoothed. Sunset and sunrise occurred during the 1900 and 0500 sample periods.*

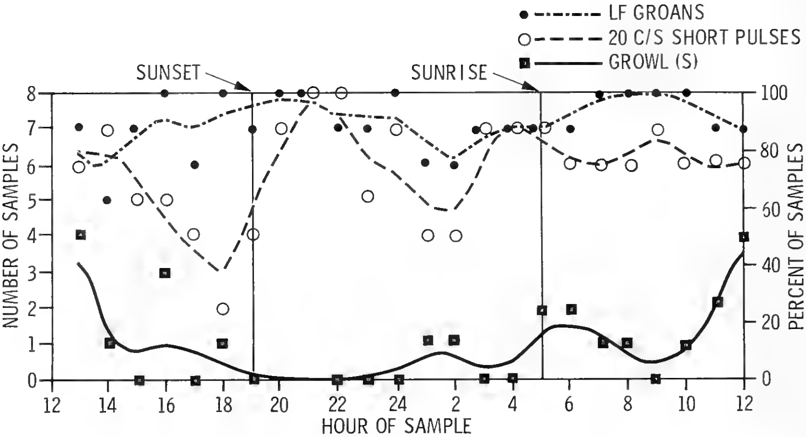



*Figure 11. Diurnal distribution curves for sounds with little diurnal patterning, based on the number of hourly samples in which a particular sound was heard, regardless of how many times within a sample it was repeated. Although the Low Frequency Groans and 20 c/s Short Pulses were characteristically of low count per sample, they were well distributed throughout the samples. The distributions of 20 c/s Long Pulses and Barking fall essentially on the 100 percent line of the graph. The curves for 20 c/s Pulses and Low Frequency Groans are based upon presence of a sound in either the deep or shallow hydrophone or both. The Growl sound was heard only from the shallow hydrophone.*

laryngeal quality of the Growl, were noticed in 17 of the deep hydrophone samples but were not dealt with further.

The rest of the sounds tabulated were low-frequency sounds, made prominent aurally only by speedup of the playback transport. Those termed Low-Frequency Groans occurred only a limited number of times during a sample period, yet they showed great probability of occurring within sample periods during any time of the day, as shown in figure 11. The 20 c/s Short Pulses were also rather sporadic, but occurred in most samples listened to and during essentially all of the samples in the 2000 to 2200 period. The 20 c/s Long Pulses are not included in these graphs because they were always detectable, even if very weak, within some part of each sample period during every hour of the day. The mean maximum S/N per sample (in a one-third octave band centered at 20 c/s) was 18.7 dB at the deep hydrophone and 23.4 dB at the shallow hydrophone. The Groans and Short Pulses occurred at both hydrophones about equally, and the curves represent presence of the sound in either or both hydrophones.

Figure 12 shows the mean number of 20 c/s Long Pulses, Short Pulses, and Low-Frequency Groans per sample as a function of time of day. As in figures 10 and 11 the curves here were plotted using the method of running averages. The number of Low-Frequency Groans increases sharply at 2000 at both hydrophones, while the peak number of 20 c/s Short Pulses occurs at 2100. Around 0400, just before dawn, occurs a peak number of 20 c/s Long Pulses and what appear to be secondary peaks in the Short Pulses and Low-Frequency Groans. As explained earlier, the decision was made to include a short pulse well above 20 c/s but below 100 c/s, not with the 20 c/s Short Pulses, but rather with the Groans (with which the questionable pulses were compatible in frequencies, but not in duration). The 20 c/s Pulses and the Low-Frequency Groans are obviously from powerful, distant sources (judging from the fact that the same pulses are heard on hydrophones 4 miles apart at approximately the same S/N). A correlation in

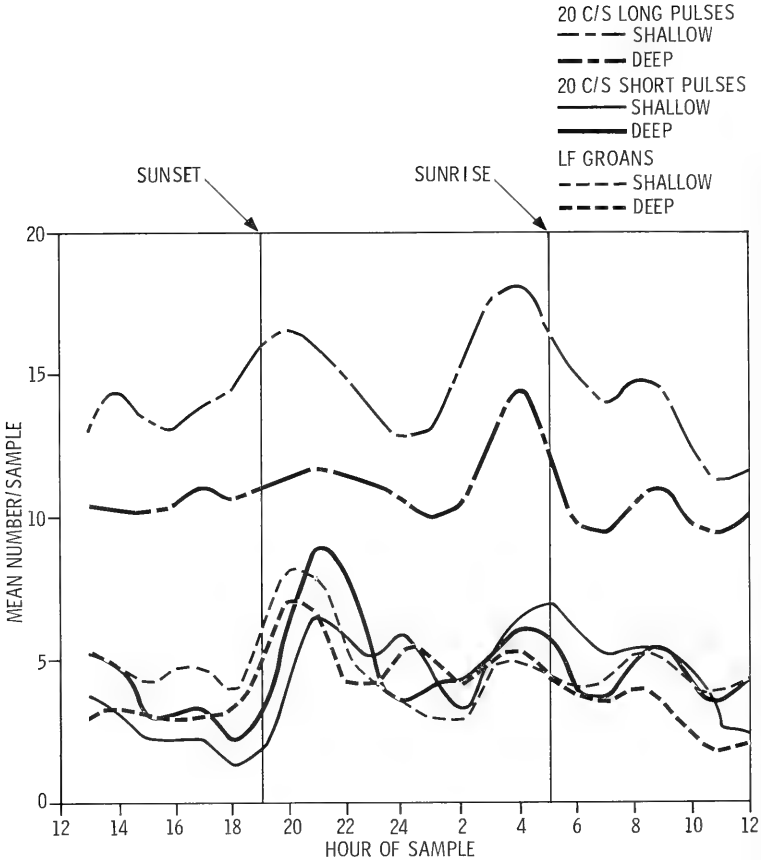



*Figure 12. Total number of sounds heard of a particular category (20 c/s Long and Short Pulses and Low Frequency Groans) during all samples of a particular time of day, divided by the number of days. The curves were smoothed arithmetically.*

count for the hydrophones appears to exist, as shown in figure 12; the difference between the deep and shallow water curves is very minor, as would be expected should most of the pulses heard at one hydrophone be the same as those heard at the other.

## DISCUSSION

Reference 1 describes and discusses the cyclic Click Chorus, the Barking, and the 20 c/s Long Pulses. An effort will be made in the present discussion to avoid unnecessary repetition of material in that report.

The listening performed in the study reported here has resulted in some conclusions as to the cause of certain diurnal variations in the minimum ambient background levels. Figures 2, 3, and 4 of reference 1, diurnal curves of (minimum) ambient levels, show the following phenomena: (1) In the shallow hydrophone output, increases in the ambient background were noted between 2000 and 0400 in the 125 to 1000 c/s region with sharp peaks at 2000 and 0400 hours (particularly in the 160 and 500 c/s region). (2) In the deep water the nocturnal increase was limited to the hours 2200 to 2400 in the frequency range 80 to 250 c/s, particularly between 100 and 160 c/s. Figure 13 was prepared from the 19-21 July data of reference 1 to emphasize these effects for shallow and deep hydrophones.

In figure 13(S), the general background spectrum at the shallow hydrophone before 2000 and after 0400 is shown as the dashed-line base, and the other curves are the spectra of base background level for the times indicated. The listening session made it abundantly clear that the 2000 hours curve is a result of the Click Chorus, which at this time of day was strong and continuous without cyclic fluctuation with time. By 2100 hours the chorus was reduced in density and intensity and was cyclic again. It

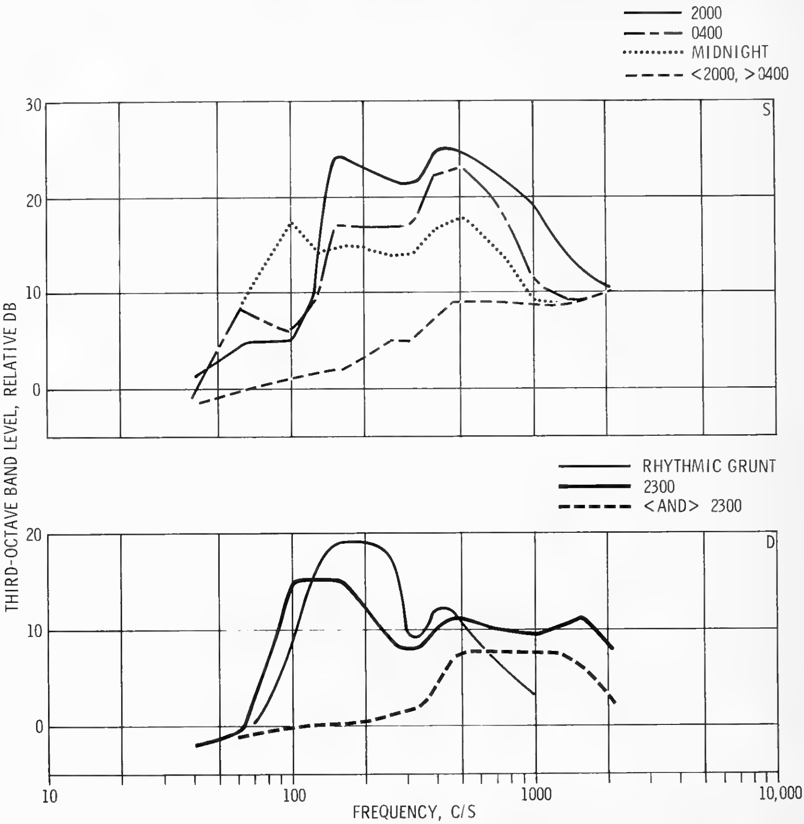



*Figure 13. Relative ambient noise spectra during nighttime hours at the shallow-water hydrophone (S) and at the deep-water hydrophone (D). The curves are based upon data shown in figures 2, 3, and 4 of reference 1 for the period 1200 on 19 July to 1200 on 21 July. The Rhythmic Grunt spectrum is based on one sample (from the shallow hydrophone, 1900, 22 July) and is the same one shown in figure 2 of the present report. The curve labeled 2300 is for the diurnal deep-water peak that extends roughly from 2200 to 2400. The base ambient noise level curve represents the general background level before and after this peak.*

remained subdued during the middle night hours and had little, if any, effect upon the midnight spectrum curve. By 0400 hours the Click Chorus had increased in intensity again and probably was the controlling agent for the base noise spectrum at this hour. However, it now was somewhat cyclic in nature and was less intense than at 2000 hours.

The question as to what the shallow hydrophone base spectrum around midnight [fig. 13(S)] should be attributed is unanswered at present. The Motorboating sound is probably responsible for the raised level in the 150-to-500 c/s region, since it was present in many of the samples representing this hour and in a wide range of intensities. But the cause of the raised spectrum below 150 c/s remains a mystery.

In figure 13(D), the dashed-line base represents the minimum levels just before and after 2300 hours at the deep hydrophone. The curve for the peak in the base ambient noise occurring at approximately 2300 hours is compared here with the spectrum curve for the Rhythmic Grunt sound, which around this hour was a dominant drone at these frequencies. The Grunt whose spectrum is shown is from the shallow hydrophone output. Closer correspondence could have been obtained using a different Grunt sample, particularly one from the output of the deep hydrophone. A typical grunt density during this period was 60 to 80 distinct grunts per minute, which, assuming a typical grunt duration of 500 msec, leaves very little time unoccupied by pulses of this sound. Presumably indistinct Rhythmic Grunts were also present, filling in the "silent" intervals.

The shallow hydrophone picked up fewer grunts, but a high proportion of them had a good S/N. Some shallow hydrophone Rhythmic Grunts had the spectrum shown, but others had a spectrum very similar to the 2300 curve between 60 and 300 c/s. On the other hand, all the Rhythmic Grunts recorded from the deep hydrophone seemed to be of the type having good level at 100 c/s like the 2300 spectrum.

Consequently, the Rhythmic Grunt sound is a prime suspect as the main cause of the elevated base ambient noise spectrum at 2300 hours in the deep water case.

In addition to being lower in frequency, on the average, the Rhythmic Grunts at the deep hydrophone were characterized by a slower repetition rate. Checks on widely scattered samples showed the following means of the Grunt repetition rate: at the shallow hydrophone, one per 4.39 sec ±0.056 (SE), one per 4.55 sec ±0.055 (SE), and one per 4.12 sec ±0.054 (SE); at the deep hydrophone, one per 5.04 sec ±0.053 (SE) and one per 5.68 sec ±0.13 (SE).* An additional sample checked for timing was part of a 15-minute towed-array sample recorded on SALUDA (IX 87) sailing at 5 knots in 6-fathom water off Black Warrior Lagoon, B. C. This sample, which was recorded on 9 February 1965, seemed almost identical to some of the San Clemente shallow samples and also revealed a very similar repetition rate: one per 4.28 sec ±0.060 (SE).

The most mysterious of all the sounds, of course, were the 20 c/s Long Pulses. They were present in every sample. Although the mean maximum S/N per sample was 18.7 dB deep and 23.4 dB shallow, many other Long Pulses were just audible. One explanation for the generally greater S/N in the shallow-hydrophone channel for 20 c/s Pulses both Long and Short is the rapid slope off of the deep hydrophone response below 40 c/s, which for the analysis band centered at 20 c/s could emphasize the noise background in the top half of the band more than the 20 c/s Pulses.

---

*SE = standard error of the mean

The mean number of 20 c/s Long Pulses per sample (10.9 deep and 14.6 shallow) corresponds to about 55 and 73 per hour, respectively, or of the order of one per minute. The counting was influenced by interpretation as to what constituted a Pulse, because at times the sounds were superimposed on each other causing a continuous and multiple jumble of sound. Counting was particularly subjective when the sounds were barely audible. For these reasons quantitative description of the Long Pulses, such as in figure 12, is open to question. This report does not describe all the variety of sounds observed, but only the frequent, repetitive sounds, especially those that have substantial influence on overall ambient levels. Of the other sounds, infrequent and sometimes obscure, one deserving at least passing comment can best be described as consisting of isolated clicks or pops doubtless from biological sources. Although these clicks and pops were sparsely spread, so that they had no effect upon mean ambient levels, they were found in at least 50 percent of the deep samples and 10 percent of the shallow samples. They were also slightly more frequent from midnight to noon than from noon to midnight.

Wenz[2] has discussed the phenomenon of hearing pinniped barking from a bottom-mounted hydrophone at 360 ft depth, and the implication was that the pinniped may be capable of barking while completely submerged. In the present study the deep receiving hydrophone at 2700 feet (450 fathoms) picked up pinniped sounds with good S/N. DeVries and Wohlschlag[12] have recorded dives of the Weddell seal in Antarctica to depths of approximately 1150 feet.

The National Science Foundation has recently reported (through a publicity release[13]) that: (1) The submerged Weddell seal produces a wide variety of noises without opening its mouth or nostrils. (2) The seal sounds are heard at depths of hundreds of feet. (3) Scuba divers associate certain throat and head movements with particular sounds. In addition, Schusterman, Kellogg, and Rice[14]

have reported barking from California sea lions submerged in a laboratory pool.

From the foregoing observations and from the fact that the pinniped signal levels in the July 1963 San Clemente tests at the 450-fathom hydrophone were well above the background noise, it seems reasonable to assume that the pinniped sound sources were submerged and possibly deeply submerged.

Finally, mention must be made of the fine listening conditions which resulted in such good S/N for the biological sound. In 69 percent of the hours sampled there was no noticeable propulsion sound at either hydrophone, and other man-made sounds such as sonar pinging were even more rare. Such conditions are remarkable for a coastal area so close to shipping lanes and show it to be a good site for further study of ambient noise phenomena.

## CONCLUSIONS

Principal conclusions from analyzing the sounds in the recorded samplings of 192 hours, from both deep water and shallow water, are:

1. The Rhythmic Grunt sound was the cause of the raised level of the minimum ambient background noise in the 100-c/s-to-160-c/s frequency region at the deep hydrophone just before midnight.

2. In shallow water the peaks in the minimum ambient noise levels in the 160-c/s-to-1000-c/s frequency region at 2000 and 0400 hours were due to the Click Chorus sound.

3. The Motorboating sound is one of the agents responsible for the ambient noise hump at the shallow hydrophone during the hours around midnight.

A dominant sound feature, which may have played a part in the base ambient noise levels at any hour and at either hydrophone, was the widely varied Barking sound. Furthermore, although at first ignored as an irrelevant and hardly heard, low-frequency disturbance, the 20 c/s Long Pulses were found to be an omnipresent fundamental in the symphony of sound in the San Nicolas Basin.

# REFERENCES


1. Navy Electronics Laboratory Report 1260, Underwater Acoustic Ambient-Noise and Transmission Tests West of San Clemente Island, by G. M. Wenz, M. A. Calderon, and R. F. Scanlan, CONFIDENTIAL, 18 January 1965

2. Wenz, G. M., "Curious Noises and the Sonic Environment in the Ocean," p. 101-119 in Symposium on Marine Bio-Acoustics, Lerner Marine Laboratory, 1963, Marine Bio-Acoustics, Macmillan, 1964

3. Navy Electronics Laboratory Report 1115, Shallow Water Ambient Noise Survey at the NEL Oceanographic Tower, by G. A. Clapp, CONFIDENTIAL, 9 July 1962

4. Clapp, G. A., "Periodic Variations of the Underwater Ambient-Noise Level of Biological Origin (Abstract)," Acoustical Society of America. Journal, v. 36, p. 1994, October 1964

5. Calderon, M., "Low-Frequency Underwater Pulsed Noise Observed in the Pacific Ocean," U. S. Navy Journal of Underwater Acoustics, v. 12, p. 729-742, CONFIDENTIAL, October 1962

6. Jensvold, R. D. and Wright, K. A., "Some Very Low-Frequency Pulsed Noises in the Atlantic Ocean," U. S. Navy Journal of Underwater Acoustics, v. 9, p. 685-704, CONFIDENTIAL, October 1959

7. Patterson, B. and Hamilton, G. R., "Low-Frequency Pulsed Signals Received on Bermuda Hydrophones," U. S. Navy Journal of Underwater Acoustics, v. 11, p. 89-108, CONFIDENTIAL, January 1961

REFERENCES (Continued)


8. Patterson, B. and Hamilton, G. R., "Repetitive 20 Cycle Per Second Biological Hydroacoustic Signals at Bermuda," p. 125-145 in Symposium on Marine Bio-Acoustics, Lerner Marine Laboratory, 1963, Marine Bio-Acoustics, Macmillan, 1964

9. Schevill, W. E. and others, "The 20-Cycle Signals and Balaenoptera (Fin Whales)," p. 147-152 in Symposium on Marine Bio-Acoustics, Lerner Marine Laboratory, 1963, Marine Bio-Acoustics, Macmillan, 1964

10. Bell Telephone Laboratories Contract NObsr-81018; Final Report, Ocean Noise Study, CONFIDENTIAL, December 1960

11. Guilford, J. P., Fundamental Statistics in Psychology and Education, p. 23, McGraw-Hill, 1942

12. DeVries, A. L. and Wohlschlag, D. E., "Diving Depths of the Weddell Seal," Science, v. 145, p. 292, 17 July 1964

13. Scientists Go Under Ice to Eavesdrop on Seals, San Diego Union, p. A-30, 13 December 1964

14. Schusterman, R. J. and others, "Underwater Visual Discrimination by the California Sea Lion," Science, v. 147, p. 1594-1596, 26 March 1965

U

Security Classification

**DOCUMENT CONTROL DATA - R&D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY *(Corporate author)*<br>Navy Electronics Laboratory<br>San Diego<br>California 92152 | 2a. REPORT SECURITY CLASSIFICATION<br>U<br>2b. GROUP |

3. REPORT TITLE

Marine Biological Sound West of San Clemente Island

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Research Report January 1964 to December 1964

5. AUTHOR(S) *(Last name, first name, initial)*

Thompson, P. O.

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| 24 May 1965 | 42 | 14 |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO.<br>b. PROJECT NO. SF 001 03 16<br>Task 8529<br>c. NEL Problem E11351<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>1290<br>9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* |

10. AVAILABILITY/LIMITATION NOTICES

Qualified Requesters May Obtain Copies of This Report From DDC

| | |
|---|---|
| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY<br>Bureau of Ships<br>Washington<br>D. C. 20360 |

13. ABSTRACT

A survey was made of the biological sound present in a set of tape recordings obtained from a hydrophone at 60 fathoms and another at 450 fathoms, over an 8-day period. A variety of types of biological sound were distinguished and analyzed. They were shown to have significant influence on the ambient noise level.

DD FORM 1 JAN 64 1473 0101-807-6800

U

Security Classification

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Marine Biological Noise | | | | | | |
| Underwater Noise | | | | | | |

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

Navy Electronics Lab., San Diego, Calif.
Report 1290

MARINE BIOLOGICAL SOUND WEST OF SAN CLEMENTE ISLAND, by P. O. Thompson, 42 p., 24 May 65.

UNCLASSIFIED

A survey was made of the biological sound present in a set of tape recordings obtained from a hydrophone at 60 fathoms and another at 450 fathoms, over an 8-day period. A variety of types of biological sound were distinguished and analyzed. They were shown to have significant influence on the ambient noise level.

1. Marine biological noise - San Clemente Island
2. Underwater noise

I. Thompson, P. O.

SF 001 03 16, Task 8529
(NEL E11351)

This card is UNCLASSIFIED

Navy Electronics Lab., San Diego, Calif.
Report 1290

MARINE BIOLOGICAL SOUND WEST OF SAN CLEMENTE ISLAND, by P. O. Thompson, 42 p., 24 May 65.

UNCLASSIFIED

A survey was made of the biological sound present in a set of tape recordings obtained from a hydrophone at 60 fathoms and another at 450 fathoms, over an 8-day period. A variety of types of biological sound were distinguished and analyzed. They were shown to have significant influence on the ambient noise level.

1. Marine biological noise - San Clemente Island
2. Underwater noise

I. Thompson, P. O.

SF 001 03 16, Task 8529
(NEL E11351)

This card is UNCLASSIFIED

Navy Electronics Lab., San Diego, Calif.
Report 1290

MARINE BIOLOGICAL SOUND WEST OF SAN CLEMENTE ISLAND, by P. O. Thompson, 42 p., 24 May 65.

UNCLASSIFIED

A survey was made of the biological sound present in a set of tape recordings obtained from a hydrophone at 60 fathoms and another at 450 fathoms, over an 8-day period. A variety of types of biological sound were distinguished and analyzed. They were shown to have significant influence on the ambient noise level.

1. Marine biological noise - San Clemente Island
2. Underwater noise

I. Thompson, P. O.

SF 001 03 16, Task 8529
(NEL E11351)

This card is UNCLASSIFIED

Navy Electronics Lab., San Diego, Calif.
Report 1290

MARINE BIOLOGICAL SOUND WEST OF SAN CLEMENTE ISLAND, by P. O. Thompson, 42 p., 24 May 65.

UNCLASSIFIED

A survey was made of the biological sound present in a set of tape recordings obtained from a hydrophone at 60 fathoms and another at 450 fathoms, over an 8-day period. A variety of types of biological sound were distinguished and analyzed. They were shown to have significant influence on the ambient noise level.

1. Marine biological noise - San Clemente Island
2. Underwater noise

I. Thompson, P. O.

SF 001 03 16, Task 8529
(NEL E11351)

This card is UNCLASSIFIED

INITIAL DISTRIBUTION LIST

SUPERVISOR OF SHIPBUILDING US NAVY
  GROTON
US NAVAL POSTGRADUATE SCHOOL
  LIBRARY (2)
  DEPT. OF ENVIRONMENTAL SCIENCES
NAVY REPRESENTATIVE
  MIT LINCOLN LABORATORY
OFFICE OF NAVAL RESEARCH
  LONDON
  BOSTON
  CHICAGO
  SAN FRANCISCO
FLEET NUMERICAL WEATHER FACILITY
US NAVAL APPLIED SCIENCE LABORATORY
  CODE 9832
US NAVAL ACADEMY
ASSISTANT SECRETARY OF THE NAVY R-D
ONR SCIENTIFIC LIAISON OFFICER
  WOODS HOLE OCEANOGRAPHIC INSTITUTION
INSTITUTE OF NAVAL STUDIES
  LIBRARY
AIR DEVELOPMENT SQUADRON ONE /VX-1/
CHARLESTON NAVAL SHIPYARD
DEFENSE DOCUMENTATION CENTER (20)
DOD RESEARCH AND ENGINEERING
  TECHNICAL LIBRARY
NATIONAL OCEANOGRAPHIC DATA CENTER(2)
NASA
  LANGLEY RESEARCH CENTER (3)
COMMITTEE ON UNDERSEA WARFARE
US COAST GUARD
  OCEANOGRAPHY - METEOROLOGY BRANCH
ARCTIC RESEARCH LABORATORY
WOODS HOLE OCEANOGRAPHIC INSTITUTION
US COAST AND GEODETIC SURVEY
  MARINE DATA DIVISION /ATTN-22/ (3)
US WEATHER BUREAU
US GEOLOGICAL SURVEY LIBRARY
  DENVER SECTION
US BUREAU OF COMMERCIAL FISHERIES
  LA JOLLA DR. AHLSTROM
  WASHINGTON 25, D. C.
  POINT LOMA STATION
  WOODS HOLE, MASSACHUSETTS
  HONOLULU-JOHN C MARR
  LA JOLLA, CALIFORNIA
  HONOLULU, HAWAII
  STANFORD, CALIFORNIA
  POINT LOMA STA-J. H. JOHNSON
ABERDEEN PROVING GROUND, MARYLAND
US ARMY ELECTRONIC PROVING GROUND
REDSTONE SCIENTIFIC INFORMATION
  CENTER
BEACH EROSION BOARD
  CORPS OF ENGINEERS, US ARMY
EDGEWOOD ARSENAL
DEPUTY CHIEF OF STAFF, US AIR FORCE
  AFRST-SC
AIR DEFENSE COMMAND
  ADOOA
STRATEGIC AIR COMMAND
ROME AIR DEVELOPMENT CENTER
HQ AIR WEATHER SERVICE
UNIVERSITY OF MIAMI
  THE MARINE LAB. LIBRARY (3)
COLUMBIA UNIVERSITY
  HUDSON LABORATORIES
  ELECTRONIC RESEARCH LABS
LAMONT GEOLOGICAL OBSERVATORY
DARTMOUTH COLLEGE
  THAYER SCHOOL OF ENGINEERING
  RADIOPHYSICS LABORATORY
RUTGERS UNIVERSITY
CORNELL UNIVERSITY
OREGON STATE UNIVERSITY
  DEPARTMENT OF OCEANOGRAPHY
UNIVERSITY OF SOUTHERN CALIFORNIA
  ALLAN HANCOCK FOUNDATION
UNIVERSITY OF WASHINGTON
  DEPARTMENT OF OCEANOGRAPHY
  FISHERIES-OCEANOGRAPHY LIBRARY
NEW YORK UNIVERSITY
  DEPT OF METEOROLOGY - OCEANOGRAPHY
UNIVERSITY OF MICHIGAN
  DR. JOHN C. AYERS (2)
UNIVERSITY OF WASHINGTON
  DIRECTOR, APPLIED PHYSICS LABORATORY
UNIVERSITY OF ALASKA
  GEOPHYSICAL INSTITUTE
UNIVERSITY OF RHODE ISLAND
  NARRAGANSETT MARINE LABORATORY
YALE UNIVERSITY
  BINGHAM OCEANOGRAPHIC LABORATORY
FLORIDA STATE UNIVERSITY
  OCEANOGRAPHIC INSTITUTE
UNIVERSITY OF HAWAII
  HAWAII INSTITUTE OF GEOPHYSICS
  ELECTRICAL ENGINEERING DEPT
A-M COLLEGE OF TEXAS
  DEPARTMENT OF OCEANOGRAPHY
THE UNIVERSITY OF TEXAS
  DEFENSE RESEARCH LABORATORY
HARVARD UNIVERSITY
SCRIPPS INSTITUTION OF OCEANOGRAPHY
  MARINE PHYSICAL LAB
PENNSYLVANIA STATE UNIVERSITY
  ORDNANCE RESEARCH LABORATORY
UNIVERSITY OF CALIFORNIA
  ENGINEERING DEPARTMENT
UNIVERSITY OF CALIFORNIA, SAN DIEGO
  SIO
MASSACHUSETTS INST OF TECHNOLOGY
  ENGINEERING LIBRARY
THE JOHNS HOPKINS UNIVERSITY
  APPLIED PHYSICS LABORATORY
INSTITUTE FOR DEFENSE ANALYSIS

CHIEF, BUREAU OF SHIPS
  CODE 1610    CODE 345B
  CODE 1620
  CODE 1631
  CODE 210L (2)
  CODE 240C (2)
  CODE 320
  CODE 360
  CODE 452E
  CODE 670 (2)
CHIEF, BUREAU OF NAVAL WEAPONS
  DLI-3
  DLI-31
  FASS
  R-56
  RUDC-2
  RUDC-11
CHIEF, BUREAU OF YARDS AND DOCKS
CHIEF OF NAVAL PERSONNEL
  PERS 11B
CHIEF OF NAVAL OPERATIONS
  OP-07T
  OP-701E1
  OP-71
  OP-76C
  OP-03EG
  OP-09B5
CHIEF OF NAVAL RESEARCH
  CODE 416
  CODE 455
  CODE 461
  CODE 466
  CODE 468
COMMANDER IN CHIEF US PACIFIC FLEET
COMMANDER IN CHIEF US ATLANTIC FLEET
COMMANDER OPERATIONAL TEST AND
  EVALUATION FORCE
DEPUTY COMMANDER OPERATIONAL TEST -
  EVALUATION FORCE, PACIFIC
COMMANDER CRUISER-DESTROYER FORCE,
  US ATLANTIC FLEET
  US PACIFIC FLEET
COMMANDER SUBMARINE FORCE
  US PACIFIC FLEET
  US ATLANTIC FLEET
DEPUTY COMMANDER SUBMARINE FORCE,
  US ATLANTIC FLEET
COMMANDER ANTISUBMARINE WARFARE FOR
  US PACIFIC FLEET
COMMANDER TRAINING COMMAND
  US PACIFIC FLEET
OCEANOGRAPHIC SYSTEM PACIFIC (2)
COMMANDER SUBMARINE DEVELOPMENT
  GROUP TWO
COMMANDER SERVICE FORCE
  US ATLANTIC FLEET
COMMANDER KEY WEST TEST -
  EVALUATION DETACHMENT
DESTROYER DEVELOPMENT GROUP PACIFIC
FLEET AIR WINGS, ATLANTIC FLEET
  SCIENTIFIC ADVISORY TEAM
US NAVAL AIR DEVELOPMENT CENTER
  NADC LIBRARY
US NAVAL MISSILE CENTER
  TECH. LIBRARY, CODE NO 3022
  CODE N3232
PACIFIC MISSILE RANGE /CODE 3250/
US NAVAL ORDNANCE LABORATORY
  LIBRARY
US NAVAL ORDNANCE TEST STATION
  PASADENA ANNEX LIBRARY
  CHINA LAKE
FLEET COMPUTER PROGRAMMING CENTER
  ATLANTIC, TECHNICAL LIBRARY
US NAVAL WEAPONS LABORATORY
  KXL
PORTSMOUTH NAVAL SHIPYARD
PUGET SOUND NAVAL SHIPYARD
USN RADIOLOGICAL DEFENSE LABORATORY
DAVID TAYLOR MODEL BASIN
  APPLIED MATHEMATICS LABORATORY
  /LIBRARY/
US NAVY MINE DEFENSE LABORATORY
US NAVAL TRAINING DEVICE CENTER
  HUMAN FACTORS DEPARTMENT
  CODE 365H, ASW DIVISION
USN UNDERWATER SOUND LABORATORY
  LIBRARY (3)
ATLANTIC FLEET ASW TACTICAL SCHOOL
USN MARINE ENGINEERING LABORATORY
US NAVAL CIVIL ENGINEERING LAB.
  L54
US NAVAL RESEARCH LABORATORY
  CODE 2027
  CODE 5120
US NAVAL ORDNANCE LABORATORY
  CORONA
USN UNDERWATER SOUND REFERENCE LAB.
BEACH JUMPER UNIT ONE
BEACH JUMPER UNIT TWO
US FLEET ASW SCHOOL
US FLEET SONAR SCHOOL
USN UNDERWATER ORDNANCE STATION
OFFICE OF NAVAL RESEARCH
  PASADENA
US NAVAL SUBMARINE BASE
  NEW LONDON
US NAVAL SHIP MISSILE SYSTEMS
  ENGINEERING STATION
USN PERSONNEL RESEARCH ACTIVITY
  WASHINGTON, D. C. 20390
USN PERSONNEL RESEARCH ACTIVITY
  SAN DIEGO
USN WEATHER RESEARCH FACILITY
US NAVAL OCEANOGRAPHIC OFFICE (2)